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TESTING OF DIFFERENT TYPES OF ″SIMPROLIT″ PLATES - AN EXAMPLE

SUMMARY

The paper consists of design analysis and experimental testing results of reinforced ″Simprolit″ plates - patented product made of expanded polystyrene, patented admixtures and water, together with necessery reinforcing steel. Two types of elements were tested: ″Simprolit″ slabs and roof plates.

The testing results show very good accordance between calculated and experimental values which are used for bearing capacity evaluation of tested lightweight concrete elements.

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1. INTRODUCTION

Simprolit is a commercial name for a patent-protected composite material made of Portland cement, expanded polystyrene granules and special additives. It is an extremely light building material, and it has very good thermo-insulating characteristics. Its physical and mechanical properties are in conformity with standard GOST R 51263-99 (polystyrene-concrete). The range values of its basic properties are: Density (150 - 300 kg/m^3); Heat conductivity coefficient (0,055 - 0,085 W/m^oC); Steam permeability (0,135 - 0,110 mg/m·h·Pa); Compressive strength (0,35 - 0,93 MPa). High frost resistance characterizes Simprolit: at 50-cycle freeze-thaw test (from +15^{o}C to -20^{o}C), loss of strength varies only from 1,5% - 1,8%. Heat conductivity practically does not depend on the moisture content in it, given an almost constant moisture percentage in material ranging between 4% - 8%. When exposed to fire, polystyrene granules vaporize, and in prolonged high temperatures the material turns into cement stone, with no smoke or flame appearing. This material is ecologically harmless, its composite toxicity indicator is about 1,5 - 2,0 times lower than values approved in the referent standards.

Simprolit is used for production of various light-concrete elements, such as: thermo-insulation facade panels, blocks for outer walls, blocks for partition walls and facade casing, pre-fabricated partition wall panels, insulation panels, slabs, roof plates, etc.

Several of these products were tested at the Faculty of Civil Engineering - Institute for materials and structures in Belgrade. In this paper some of design and experimental results analysis made during testing of Simprolit slabs and roof plates will be presented.

2. TESTING OF SIMPROLIT SLABS

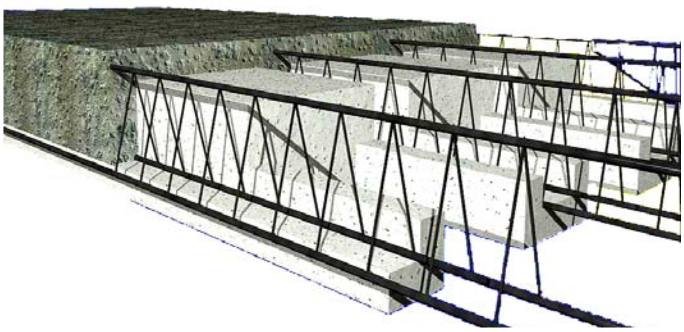
Simprolit slab (SMP Type 1) represents reinforced concrete structure with a cross-section shown on the Figure 1. First, the slab was tested before additional concreting. As one can see, it is a composite system which consists of Styropore, glue and Simprolit, together with necessary steel reinforcement. The testing specimen was 75 cm wide and 167 cm long. For adopted dimensions and quantity of reinforcement in the given element, assuming that in this case the present steel reinforcement with yield stress of σ_v = 400 MPa carries the whole load, the ultimate moment value was calculated:

$$M_u = 400 \cdot 2{,}31 \cdot 9{,}5 \cdot 10^{-3} = 8{,}78 \text{ kNm}.$$

For this testing the statical system with one force in the middle of 150 cm span was adopted, which means that ultimate bending force (force at failure point) amounts to:

$$P_u = \frac{4 \times M_u}{l} = \frac{4 \times 8{,}78}{1{,}5} = 23{,}4 \text{ kN}.$$

Figure 1 Simprolit slab



During the test only the deflection of the system was measured using two deflectometers (U_1 and U_2) placed under the element at the midsection near the left and right end of the 75 cm wide plate. Using this disposition it was possible to calculate precise slab deflection at the middle of the span as a mean value of the two measured values (d_m).

In the following table the calculated slab deflections, as well as the corresponding values of the applied force ranging from zero to the ultimate point are presented.

Table 1 The testing results for SMP slab - Phase I (before additional concreting)

Force P (kN)	Deflectometer readings U_1	U_2	Deflection d_m (mm)
0	05 96	01 53	0
1,25	06 18	01 81	0,25
2,50	06 37	01 93	0,40
3,75	06 71	02 28	0,75
5,00	07 25	02 88	1,32
7,50	08 82	04 51	2,92
10,00	09 43	05 25	3,60
12,50	10 29	06 10	4,45
15,00	11 55	07 40	5,73
17,50	13 45	09 20	7,58
20,00	17 85	13 75	12,05
27,50	Failure point		

The testing results are also presented in the form of force (P) vs. deflection (d) diagram (Fig. 2).

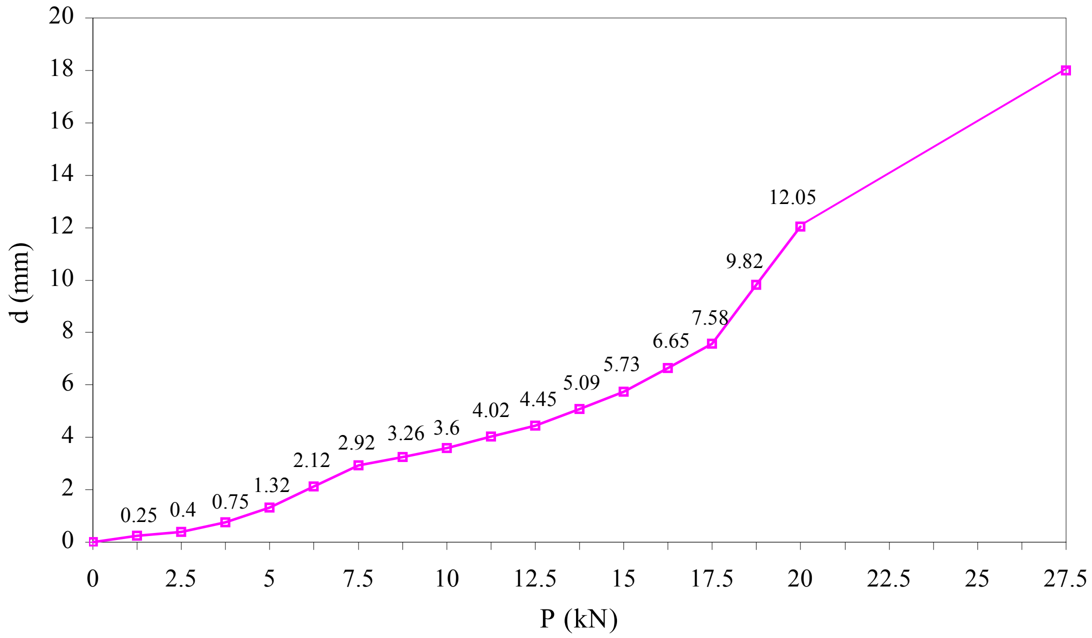


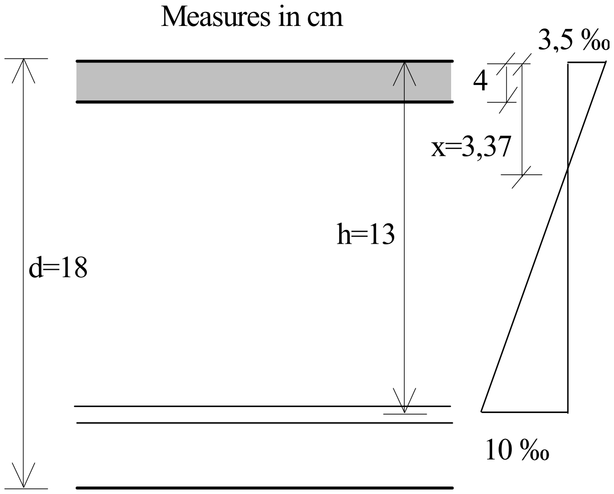
Figure 2 Force versus deflection diagram of SMP slab at bending - Phase before additional concreting (Phase I)

Based on the presented testing results the following conclusions can be made:

- The experimentally established value of Simprolit slab bearing capacity at Phase I coincides to a large extent with designed - calculated value.
- In the diagram area corresponding to additional concrete load carried by the Simprolit slab, approximately linear relation between force and deflection is valid - which means that the tested element shows significant elastic behavior.

The procedure following Phase I consist of casting of additional 4 cm thick reinforced concrete layer over the SMP slab. At this phase (Phase II) reinforced concrete beams which are used to transfer the load on vertical elements (walls, columns, etc.) were also casted on both ends of the slab.

Prior to the experimental testing, the calculation has been made in order to obtain the ultimate moment value of the SMP slab at Phase II. This calculation is presented in the following paragraph.



$$A_{a1} = 1,37 + 2,31 = 3,68\ cm^2$$

$$\sigma_a = 400\ MPa$$

$$x = \frac{3,5}{3,5+10,0} \cdot 13 = 3,37\ cm$$

$$\mu_m = \frac{3,68}{75 \cdot 18} \cdot 100 = 0,273\ \%$$

$$\overline{\mu}_m = 0,273 \times \frac{400}{14} = 7,80\ \%$$

Assumed class of concrete: C 20 $\rightarrow$ $f_b = 14$ MPa ($k = 3,67$; $s = 0,135$; $\varepsilon_b = 1,56$ ‰; $\varepsilon_a = 10,00$ ‰)

$$M_{au} = \left(\frac{h}{k}\right)^2 \cdot f_b \cdot b \cdot 10^{-3} = \left(\frac{13}{3,67}\right)^2 \times 14 \times 75 \times 10^{-3} = 13,2\ kNm$$

The statical system consisted of a simple beam with one force in the middle of 185 cm span. Thus, the ultimate bending force (force at failure point) can be calculated as:

$$P_u = \frac{4 \times M_{au}}{l} = \frac{4 \times 13,2}{1,85} = 28,5\ kN \approx 29\ kN$$

During the bending test the load change was controlled using dynamometer with sufficient accuracy. The deflection of the slab was measured using two instruments placed at the middle of the span (labeled U_1 and U_2). The strains of the element were measured by means of two deformeters (labeled D_1 and D_2). These instruments were placed in the following way:

- Deflectometers under the slab - near the ends of the cross-section.
- Deformeters on the upper side of the slab - approximately at the ends of the cross-section (in the compressed concrete zone).

In the Table 2 the calculated force, deflection and strain values based on the instrument readings are presented.

Based on the presented testing results the following conclusions can be made:

- The experimentally established value of Simprolit slab bearing capacity at Phase II is by far larger then designed - calculated value.
- In the large part of the load area (P) approximately linear relation between force and deflection is valid - which means that the tested slab shows significant elastic behavior.
- The plastic (permanent) strain values are within acceptable limits.

Table 2 The testing results for SMP slab - Phase II (after additional concreting)

Force P (kN)	Deflectometer readings		Deflection (mean value) d_m (mm)	Deformeter readings		Strain (mean value) ε_m (‰)
	U_1	U_2		D_1	D_2	
0	02 26	04 22	0	24 34	24 80	0
2,5	02 55	04 55	0,31	24 25	24 72	0,034
5,0	02 98	05 03	0,76	24 14	24 64	0,072
7,5	03 50	05 60	1,31	24 05	24 55	0,108
10,0	04 07	06 14	1,86	24 00	24 43	0,146
12,5	04 60	06 67	2,40	23 90	24 37	0,174
15,0	05 09	07 14	2,88	23 84	24 30	0,200
0	02 80	04 81	0,56	24 30	24 80	0,008
2,5	03 10	05 24	0,93	24 22	24 72	0,040
5,0	03 57	05 67	1,38	24 15	24 61	0,076
7,5	04 00	06 06	1,79	24 09	24 53	0,104
10,0	04 39	06 48	2,19	24 00	24 43	0,146
12,5	04 83	06 90	2,62	23 90	24 40	0,168
15,0	05 21	07 25	2,99	23 85	24 30	0,198
17,5	05 84	07 65	3,50	23 79	24 23	0,224
20,0	06 26	08 28	4,03	23 70	24 18	0,252
22,5	06 86	08 77	4,58	23 62	24 10	0,284
25,0	07 42	09 55	5,24	23 50	24 00	0,328
27,5	07 85	10 05	5,71	23 48	23 94	0,344
30,0	08 42	10 73	6,34	23 40	23 85	0,378
32,5	08 96	11 40	6,94	23 30	23 76	0,416
35,0	09 70	13 30	8,26	23 20	23 70	0,448
90,0	Failure			Failure		

The diagram showing relation between force (P) and deflection (d) is given below (Fig. 3).

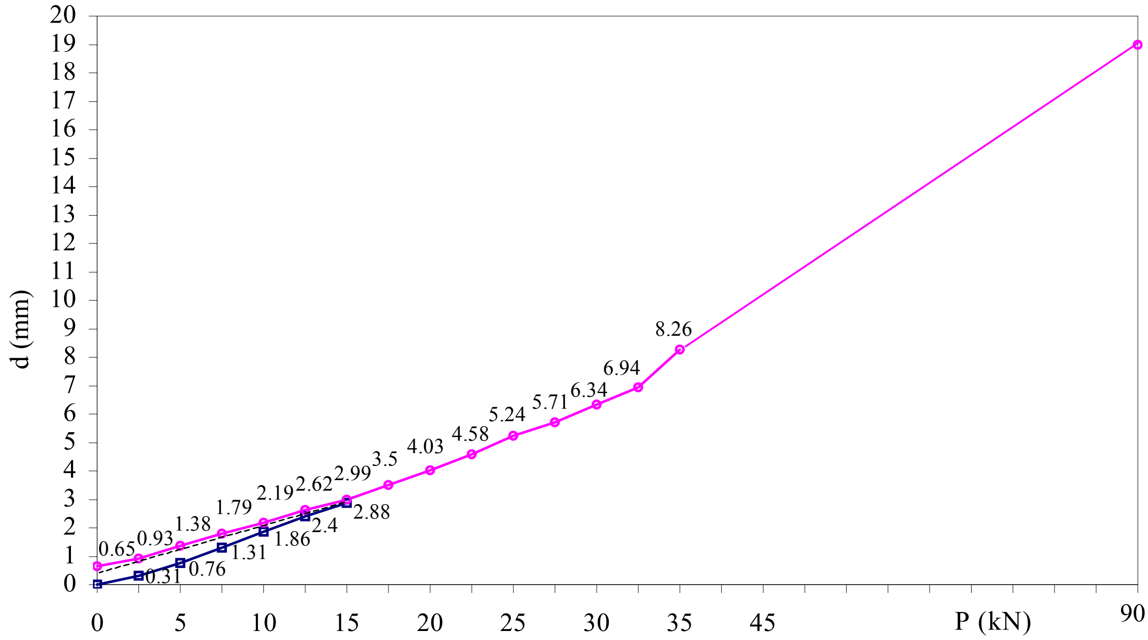


Figure 3 Force versus deflection diagram of SMP slab at bending (Phase II)

3. TESTING OF SIMPROLIT ROOF PLATES

Simprolit roof plate (SKP Type 1) also represents reinforced concrete structure, but it is a system based solely on Simprolit, reinforced with symmetrically placed steel reinforcement (space truss called ″binor″).

The testing specimen was 50 cm wide and 200 cm long Simprolit roof plate. For adopted dimensions and quantity of reinforcement in the given element, assuming that in this case the present steel reinforcement with yield stress of σ_v = 400 MPa carries the whole load, the ultimate moment value was calculated:

$$M_u = 400 \cdot 0{,}38 \cdot 5 \cdot 10{,}5 \cdot 10^{-3} = 7{,}98 \text{ kNm.}$$

For this testing the statical system with one force in the middle of 180 cm span was adopted, which means that ultimate bending force (force at failure point) amounts to:

$$P_u = \frac{4 \times M_u}{l} = \frac{4 \times 7{,}98}{1{,}8} = 17{,}7 \text{ kN.}$$

As in the other two experiments, during the bending test the load change was controlled using dynamometer with sufficient accuracy. Also, only the deflection of the system was measured using two deflectometers (U_1 and U_2) placed under the element at the midsection near the left and right end of the 50 cm wide plate. Using this disposition it was possible to calculate precise slab deflection at the middle of the span as a mean value of the two measured values.

Before the testing, the weight of the whole plate was measured - m = 60,1 kg, which means that this structure has arial mass of just 60 kg/m^2, i.e. density that amounts to 500 kg/m^3.

In the following table the calculated deflections of the plate, as well as the corresponding values of the applied force ranging from zero to the ultimate point are presented.

Table 3 The testing results for SKP (Type 1)

Force P (kN)	Deflectometer readings		Deflection d_m (mm)
	U_1	U_2	
0	02 34	05 32	0
2,5	03 71	07 25	1,65
5,0	05 17	08 80	3,16
7,5	06 75	10 53	4,81
10,0	08 30	12 15	6,40
12,5	09 87	13 63	7,92
15,0	11 70	15 39	9,72
17,5	13 63	17 39	11,68
20,0	16 10	19 65	14,04
20,6	Failure point		
22,5	20 76	22 88	17,99
0	07 71	10 87	5,46

The diagram showing relation between measured force (P) and deflection (d) is given below.

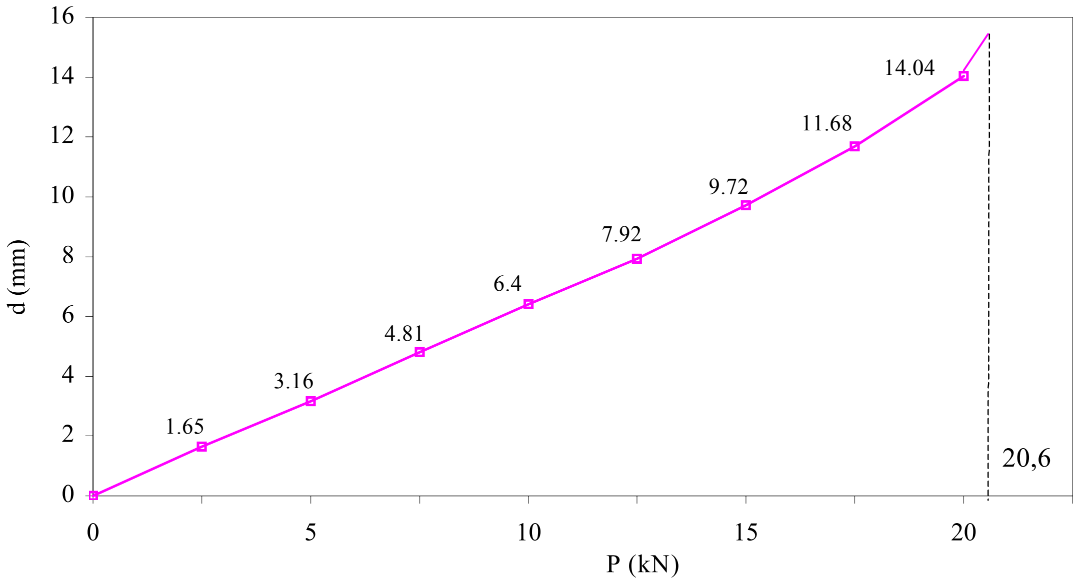


Figure 4 Force versus deflection diagram of SKP roof plate at bending

Based on the presented testing results the following conclusions can be made:

- The experimentally established value of Simprolit roof plate bearing capacity coincides to a large extent with designed - calculated value.
- Practically in the whole area of the load diagram (P) linear relation between force and deflection is valid - which means that the tested element shows significant elastic behavior.

4. CONCLUSIONS

The results presented in this paper show that there is a high degree of conformity between calculated and experimentally obtained values which are essential for evaluation of the bearing capacity of the given elements. This means that Simprolit slabs (SMP Type 1) may be used as elements for concrete structures which are executed in two phases; phase I - mounting of 75 cm wide slab elements into their position in the structure, and phase II - concreting of additional 4 cm thick reinforced concrete layer, without special formwork. Thus, for application of this type of structure with various spans and loads, all the conventional design methods may be used.

Identical conclusion can be derived in the case of Simprolit roof plates. These plates can also be designed using conventional methods for reinforced concrete structures design, adjusting their dimensions to various spans and loads.

Therefore, the general conclusion can be made that each of the tested elements fulfils all the necessary conditions for practical application. Logically, it is assumed that their application must be completely in accordance to the conditions given by the producer. Testing of Simprolit elements was a part of a larger research project sponsored by the Serbian Ministry of Science, concerning implementation and application of up-to-date structural materials

REFERENCES

1. Jevtić D., Dević M., Zakić D.: ″Svojstva i primena Simprolita – patentiranog polistirolbetona″, Simpozijum JUDIMK-a o istraživanjima i primeni savremenih dostignuća u našem građevinarstvu u oblasti materijala i konstrukcija, Zbornik radova, str 73-79, Niška Banja, 2002.
2. Dević M., Jevtić D., Zakić D.: Simprolit elementi za gradnju - kompleksan pristup utopljavanju objekata, Konferencija ″Savremena gra|evinska praksa 2003″, FTN i DGiTNS, Zbornik radova - str. 199-215, Novi Sad, 27.-28. mart 2003.
3. Muravljov M., Jevtić D.: ″Građevinski materijali 2″, Građevinski fakultet, Beograd, 1999.
4. Preduzeće za inženjering, konsalting i promet SIMPRO Beograd, www.simprolit.com : Katalozi.
5. Institut za materijale i konstrukcije: ″Izveštaj o ispitivanju kvaliteta SIMPROLIT izolacionih panela″, IMK, Građevinski fakultet, Beograd, 2001.
6. Institut za materijale i konstrukcije: ″Izveštaj o ispitivanju kvaliteta blokova za zidanje spoljašnjih zidova SIMROLIT SB30 i SIMPROLIT SB25 i blokova za pregradne zidove SIMPROLIT SPB50 i SIMPROLIT SPB60″, IMK, Građevinski fakultet, 2001.